2024

Section A

1. A thin plastic rod is bent into a circular ring of radius R. It is uniformly charged with charge density λ. The magnitude of the electric field at its centre is :

(A) $\frac{\lambda}{2\varepsilon_0 R}$ (B) Zero (C) $\frac{\lambda}{4\pi\varepsilon_0 R}$ (D) $\frac{\lambda}{4\varepsilon_0 R}$

1. Two charged particles P and Q, having the same charge but different masses m_P and m_Q, start from rest and travel equal distances in a uniform electric field $\vec{E}$ in time t_P and t_Q respectively. Neglecting the effect of gravity, the ratio $\left(\frac{t_P}{t_Q}\right)$ is :

(A) $\frac{m_P}{m_Q}$ (B) $\frac{m_Q}{m_P}$

(C) $\sqrt{\frac{m_P}{m_Q}}$ (D) $\sqrt{\frac{m_Q}{m_P}}$

2. Two identical small conducting balls B_1 and B_2 are given -7 pC and + 4 pC charges respectively. They are brought in contact with a third identical ball B_3 and then separated. If the final charge on each ball is -2 pC, the initial charge on B_3 was

(A) -2 pC (B) -3 pC

(C) -5 pC (D) -15 pC

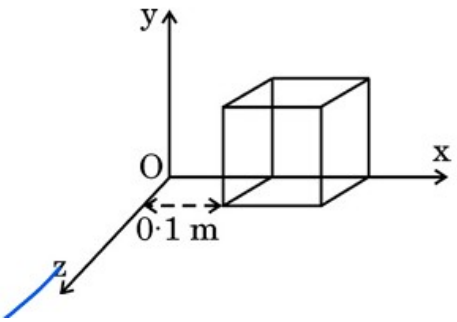
Section B

Section C

22. A cube of side 0·1 m is placed, as shown in the figure, in a region where electric field $\vec{E} = 500\, x\, \hat{i}$ exists. Here x is in meters and E in NC^{-1}. Calculate :

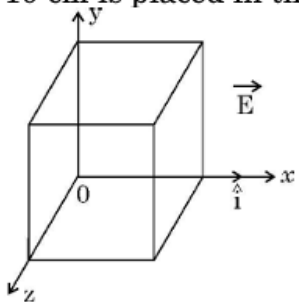
(a) the flux passing through the cube, and

(b) the charge within the cube.



(b) (i) Using Gauss's law, show that the electric field $\vec{E}$ at a point due to a uniformly charged infinite plane sheet is given by $\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}$ where symbols have their usual meanings.

(ii) Electric field $\vec{E}$ in a region is given by
$\vec{E} = (5x^2 + 2)\hat{i}$
where E is in N/C and x is in meters.
A cube of side 10 cm is placed in the region as shown in figure.



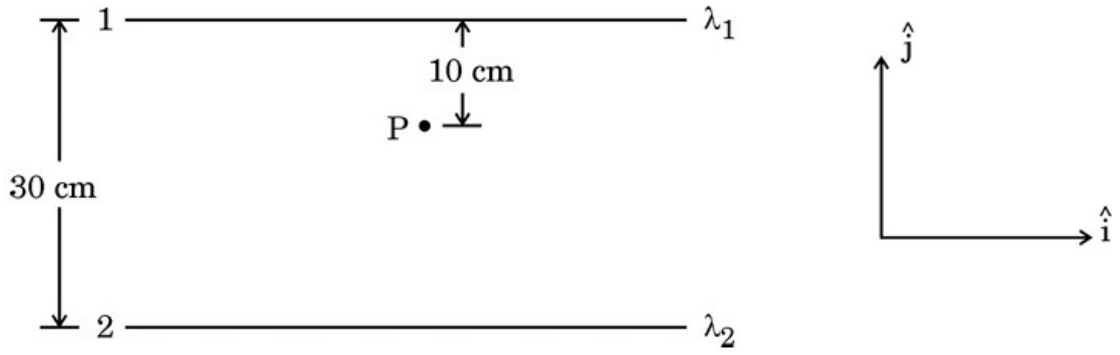
Calculate (1) the electric flux through the cube, and (2) the net charge enclosed by the cube. **5**

Section D

Section E:

(b) (i) **State Gauss's Law in** electrostatics. Apply this to obtain the electric field $\vec{E}$ at a point near a uniformly charged infinite plane sheet.

(ii) Two long straight wires 1 and 2 are kept as shown in the figure. The linear charge density of the two wires are $\lambda_1 = 10\ \mu C/m$ and $\lambda_2 = -20\ \mu C/m$. Find the net force $\vec{F}$ experienced by an electron held at point P.



OR

31 (b) (i) A charge + Q is placed on a thin conducting spherical shell of radius R. **Use Gauss's theorem to derive** an expression for the electric field at a point lying (i) inside and (ii) outside the shell.

(ii) Show that the electric field for same charge density (σ) is twice in case of a conducting plate or surface than in a nonconducting sheet. *5*

2023

Section A

1. A point charge situated at a distance 'r' from a short electric dipole on its axis, experiences a force $\vec{F}$. If the distance of the charge is '2r', the force on the charge will be :

(a) $\frac{\vec{F}}{16}$ (b) $\frac{\vec{F}}{8}$ (c) $\frac{\vec{F}}{4}$ (d) $\frac{\vec{F}}{2}$

1. The magnitude of the electric field due to a point charge object at a distance of 4.0 m is 9 N/C. From the same charged object the electric field of magnitude, 16 $\frac{N}{C}$ will be at a distance of **1**

(a) 1 m (b) 2 m
(c) 3 m (d) 6 m

1. An electron experiences a force $(1{\cdot}6 \times 10^{-16}\ N)\ \hat{i}$ in an electric field $\vec{E}$. The electric field $\vec{E}$ is :

(a) $(1{\cdot}0 \times 10^{3}\ \frac{N}{C})\ \hat{i}$ (b) $-(1{\cdot}0 \times 10^{3}\ \frac{N}{C})\ \hat{i}$

(c) $(1{\cdot}0 \times 10^{-3}\ \frac{N}{C})\ \hat{i}$ (d) $-(1{\cdot}0 \times 10^{-3}\ \frac{N}{C})\ \hat{i}$

1. Two charges q_1 and q_2 are placed at the centres of two spherical conducting shells of radius r_1 and r_2 respectively. The shells are arranged such that their centres are d $[> (r_1 + r_2)]$ distance apart. The force on q_2 due to q_1 is :

(a) $\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{d^2}$ (b) $\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{(d - r_1)^2}$

(c) Zero (d) $\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{[d - (r_1 + r_2)]^2}$

1. An electric dipole of length 2 cm is placed at an angle of 30° with an electric field 2×10^5 N/C. If the dipole experiences a torque of 8×10^{-3} Nm, the magnitude of either charge of the dipole, is **1**

(A) 4 μC (B) 7 μC
(C) 8 mC (D) 2 mC

Section B
Section C

26. (a) Two charged conducting spheres of radii a and b are connected to each other by a wire. Find the ratio of the electric fields at their surfaces. **3**

Section D

31. (a) (i) Use Gauss' law to obtain an expression for the electric field due to an infinitely long thin straight wire with uniform linear charge density λ.

(ii) An infinitely long positively charged straight wire has a linear charge density λ. An electron is revolving in a circle with a constant speed v such that the wire passes through the centre, and is perpendicular to the plane, of the circle. Find the kinetic energy of the electron in terms of magnitudes of its charge and linear charge density λ on the wire.

(iii) Draw a graph of kinetic energy as a function of linear charge density λ. **5**

31. (a) (i) State Coulomb's law in electrostatics and write it in vector form, for two charges.

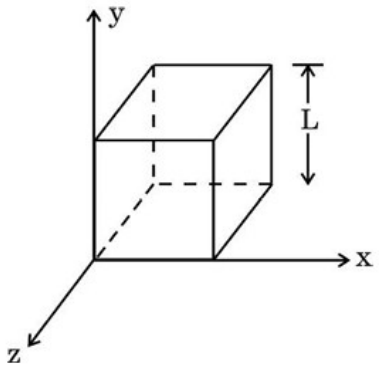
(ii) 'Gauss's law is based on the inverse-square dependence on distance contained in the Coulomb's law.' Explain.

(iii) Two charges A (charge q) and B (charge 2q) are located at points (0, 0) and (a, a) respectively. Let $\hat{i}$ and $\hat{j}$ be the unit vectors along x-axis and y-axis respectively. Find the force exerted by A on B, in terms of $\hat{i}$ and $\hat{j}$. *5*

31. (a) (i) Define electric flux and write its SI unit.

(ii) **Use Gauss' law to obtain the expression for the electric field** due to a uniformly charged infinite plane sheet.

(iii) A cube of side L is kept in space, as shown in the figure. An electric field $\vec{E} = (Ax + B)\,\hat{i}\ \frac{N}{C}$ exists in the region. Find the net charge enclosed by the cube. *5*

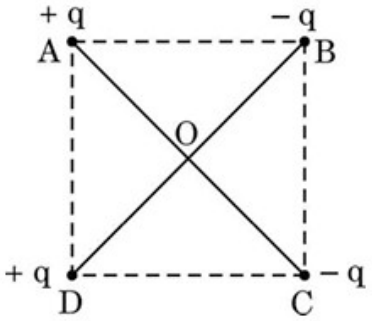


OR

(b) (i) Derive an expression for the electric field at a point on the equatorial plane of an electric dipole consisting of charges q and – q separated by a distance 2a.

(ii) The distance of a far off point on the equatorial plane of an electric dipole is halved. How will the electric field be affected for the dipole ?

(iii) Two identical electric dipoles are placed along the diagonals of a square ABCD of side $\sqrt{2}$ m as shown in the figure. Obtain the magnitude and direction of the net electric field at the centre (O) of the square. *5*



Section E

2020

Section A

Note : Fill in the blanks with appropriate answer.

11. Torque acting on an electric dipole placed in an electric field is maximum when the angle between the electric field and the dipole moment is _____. **1**

2. The electric flux emerging out from 1 C charge is

(A) $\frac{1}{\varepsilon_0}$

(B) 4π

(C) $\frac{4\pi}{\varepsilon_0}$

(D) ε_0

7. The electric flux through a closed Gaussian surface depends upon
   (a) Net charge enclosed and permittivity of the medium
   (b) Net charge enclosed, permittivity of the medium and the size of the Gaussian surface
   (c) Net charge enclosed only
   (d) Permittivity of the medium only **1**

1. If the net electric flux through a closed surface is zero, then we can infer *1*

(A) no net charge is enclosed by the surface.

(B) uniform electric field exists within the surface.

(C) electric potential varies from point to point inside the surface.

(D) charge is present inside the surface.

Note : Fill in the blanks with appropriate answer.

11. The physical quantity having SI unit NC^{-1} m is _____. **1**

13. A point charge is placed at the centre of a hollow conducting sphere of internal radius 'r' and outer radius '2r'. The ratio of the surface charge density of the inner surface to that of the outer surface will be _____. **1**

Note : *Fill in the blanks with appropriate answer :*

11. If the electric flux entering and leaving a closed surface in air are ϕ_1 and ϕ_2 respectively, the net electric charge enclosed within the surface is _____ . *1*

Section B

Section C

28. A hollow conducting sphere of inner radius r_1 and outer radius r_2 has a charge Q on its surface. A point charge –q is also placed at the centre of the sphere.

(a) What is the surface charge density on the (i) inner and (ii) outer surface of the sphere ?

(b) Use Gauss' law of electrostatics to obtain the expression for the electric field at a point lying outside the sphere. **3**

OR

(a) An infinitely long thin straight wire has a uniform linear charge density λ. Obtain the expression for the electric field (E) at a point lying at a distance *x* from the wire, using Gauss' law.

(b) Show graphically the variation of this electric field E as a function of distance *x* from the wire. **3**

Section D

35. (a) An electric dipole of dipole moment $\vec{p}$ is placed in a uniform electric field $\vec{E}$ at an angle θ with it. Derive the expression for torque ($\vec{\tau}$) acting on it. Find the orientation of the dipole relative to the electric field for which torque on it is (i) maximum, and (ii) half of maximum.

(b) Two point charges $q_1 = +1\ \mu C$ and $q_2 = +4\ \mu C$ are placed 2 m apart in air. At what distance from q_1 along the line joining the two charges, will the net electric field be zero ? *5*

37. (a) Write two important characteristics of equipotential surfaces.

(b) A thin circular ring of radius r is charged uniformly so that its linear charge density becomes λ. Derive an expression for the electric field at a point P at a distance x from it along the axis of the ring. Hence, prove that at large distances ($x >> r$), the ring behaves as a point charge. **5**

OR

(a) State Gauss's law on electrostatics and derive an expression for the electric field due to a long straight thin uniformly charged wire (linear charge density λ) at a point lying at a distance r from the wire.

(b) The magnitude of electric field (in NC^{-1}) in a region varies with the distance r(in m) as

$$E = 10\,r + 5$$

By how much does the electric potential increase in moving from point at r = 1 m to a point at r = 10 m. **5**

35. (a) Use Gauss's law to show that due to a uniformly charged spherical shell of radius R, the electric field at any point situated outside the shell at a distance r from its centre is equal to the electric field at the same point, when the entire charge on the shell were concentrated at its centre. Also plot the graph showing the variation of electric field with r, for $r \leq R$ and $r \geq R$.

(b) Two point charges of + 1 μC and + 4 μC are kept 30 cm apart. How far from the + 1 μC charge on the line joining the two charges, will the net electric field be zero ? *5*

35. (a) Using Gauss law, derive expression for electric field due to a spherical shell of uniform charge distribution σ and radius R at a point lying at a distance x from the centre of shell, such that

(i) $0 < x < R$, and

(ii) $x > R$.

(b) An electric field is uniform and acts along + x direction in the region of positive x. It is also uniform with the same magnitude but acts in – x direction in the region of negative x. The value of the field is $E = 200$ N/C for $x > 0$ and $E = -200$ N/C for $x < 0$. A right circular cylinder of length 20 cm and radius 5 cm has its centre at the origin and its axis along the x-axis so that one flat face is at $x = +10$ cm and the other is at $x = -10$ cm.

Find :

(i) The net outward flux through the cylinder.

(ii) The net charge present inside the cylinder. *5*

OR

Section E